

**PL-TR-97-2115**

**RESEARCH TO DEVELOP AUTOMATED  
TARGET BUILDING CAPABILITIES FOR ACT/EOS**

**Leonard J. Rodriguez  
Keith R. Johnson**

**ThermoAnalytics, Inc.  
94X Airport Road  
P.O. Box 66  
Calumet, Michigan 49913-0066**

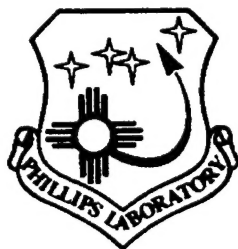
**29 August 1997**

DTIC QUALITY INSURED 2

**Final Report  
July 1996 - August 1997**

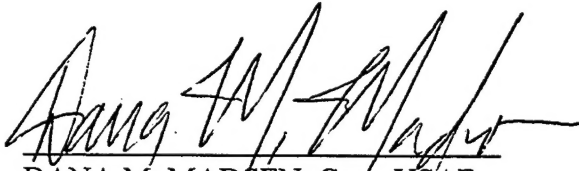
19980116 044

**Approved for public release; distribution unlimited.**




**PHILLIPS LABORATORY  
Directorate of Geophysics  
AIR FORCE MATERIEL COMMAND  
HANSCom AFB, MA 01731-3010**

This technical report has been reviewed and is approved for publication

  
DANA M. MADSEN, Capt, USAF  
Contract Manager

  
PAUL TATTELMAN, Chief  
Forecast Applications Branch

  
WILLIAM A. M. BLUMBERG  
Director, Optical Effects Division

**This report has been reviewed by the ESC Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS).**

Qualified Requestors may obtain additional copies from the Defense Technical Information Center (DTIC). All others should apply to the National Technical Information Service (NTIS).

If your address has changed, if you wish to be removed from the mailing list, or if the addressee is no longer employed by your organization, please notify PL/IM, 29 Randolph Road, Hanscom AFB, MA 01731-3010. This will assist us in maintaining a current mailing list.

Do not return copies of this report unless contractual obligations of notices or a specific document require that it be returned.

**REPORT DOCUMENTATION PAGE**Form Approved  
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 29 August 1997	3. REPORT TYPE AND DATES COVERED Final July 1996 – August 1997
4. TITLE AND SUBTITLE Research to Develop Automated Target Building Capabilities for ACT/EOS			5. FUNDING NUMBERS Contract F19628-96-C-0114
6. AUTHORS Leonard Rodriguez Keith Johnson			PE 63707F PR 2688 TA GU WU ND
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) ThermoAnalytics, Inc. 94X Airport Road PO Box 66 Calumet, MI 49913-0066			8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Phillips Laboratory 29 Randolph Road Hanscom AFB, MA 01731-3010 Contract Manager: D. Madsen, Capt., USAF/GPOF			10. SPONSORING/MONITORING AGENCY REPORT NUMBER PL-TR-97-2115
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited			12b. DISTRIBUTION CODE
13. ABSTRACT (Maximum 200 words)  This research program developed a new modeling tool, which allows the user to build new target models for infrared signature prediction and scene simulation. A methodology is used that provides the user with an ease-of-use target building capability. The program was comprised of a task that gives the user an efficient tool to build targets for ACT/EOS (and other related government programs such as SWOE). This development program focused on tools for a research environment with direct extensions for future application to field operations.			
14. SUBJECT TERMS Generic Target Builder, Generic Processor, Signature, IR, Thermal Models, ACT/EOS, TDA, Electro-Optics, Scene Simulation			15. NUMBER OF PAGES 26
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT SAR

NSN 7540-01-280-5500

Computer Generated

STANDARD FORM 298 (Rev 2-89)  
Prescribed by ANSI Std Z39-18  
298-102



## Table of Contents

<u>Section</u>	<u>Page</u>
1. INTRODUCTION .....	1
2. PROGRAM OPERATION .....	1
2.1 Example Model and Terminology .....	2
2.2 Main Window .....	2
2.3 File Menu .....	3
2.3.1 (File) New .....	3
2.3.2 (File) Open .....	4
2.3.3 (File) Save .....	5
2.3.4 (File) Save-As .....	5
2.3.5 (File) Quit .....	5
2.4 Edit Menu .....	5
2.4.1 (Edit) Dimensions .....	6
2.4.1.1 (Edit Dimension) Dismiss .....	6
2.4.1.2 (Edit Dimension) Delete .....	6
2.4.1.3 (Edit Dimension) Edit .....	7
2.4.2 (Edit) Properties .....	11
2.4.2.1 To Add a Part .....	12
2.4.2.2 Assigning Surface Elements to Surface Parts .....	13
2.4.2.3 (Edit Properties) Define Properties .....	14
2.5 Options Menu .....	18
3. DISCUSSION .....	18
APPENDIX .....	19
A.1 RPN Expressions .....	19

## List of Figures

<u>Figure</u>	<u>Page</u>
1. Generic Model Builder Main Window .....	2
2. File Menu .....	3
3. Model Drawing Window .....	4
4. Edit Menu .....	5
5. Edit Dimensions Selection Window .....	6
6. Edit Selected Dimension .....	7
7. Transformation Direction Reference Points Selection .....	8
8. Scale Direction Line with "From", "To", and "Center" Points .....	9
9. (Edit Properties) Part Selection Dialog .....	12
10. Assigning an Element to a Surface Part, the Drum's Top .....	14
11. Define Properties Window .....	15
12. Surface Selection List .....	16
13. Editing Part Layers .....	17
14. Options Menu .....	18

## **Preface**

The work was performed by ThermoAnalytics, Inc. under contract F19268-96-C-0114 for the Geophysics Directorate of Phillips Laboratory at Hanscom AFB, MA. The program manager was Keith R. Johnson and the technical lead was Dr. Leonard J. Rodriguez.

The contract was under the direction of Dana M. Madsen, Ph.D, Capt, USAF of PL/GPOF.

## 1. INTRODUCTION

The main product of this work is the generic target builder program, the computer program **genbuild**. Starting with the surface geometry of a target in AutoCAD **dxf** text format and some knowledge of its construction details, a knowledgeable person can use **genbuild** to construct a generic thermal infrared model of the target. The model is generic and can define a class of targets in the sense that the modeler can define adjustable dimensions, such as lengths and widths, and can construct lists of materials and surface finishes for various parts of the model. The generic model can then be processed by the program **xwtherm**<sup>1</sup>. Using **xwtherm** to choose final values for the dimensions, materials, and finishes, the **xwtherm** user can create one or more specific instances of the **genbuild** generic model tailored to best represent actual targets of interest. The specific models generated by **xwtherm** can then be input to **TCM2**, an infrared signature prediction program<sup>2</sup>, whose output can be used for target-in-scene modeling and signature analysis.

The generic target approach has been in use for several years for the creation of specific instance models in the infrared and other sensor bands of interest to the military. There are relatively few generic targets because construction of the targets was largely done by 'hand'. The process was expensive, time-consuming, error-prone, and limited to a very small group of practitioners. The generic target builder will greatly improve this situation by reducing the effort and increasing the speed with which a generic target can be constructed. Although information about the target and some expertise in thermal and infrared modeling will still be required to produce a good generic model, a much wider group of potential users will be able to construct more detailed generic models than was possible in the past.

Since the purpose of **genbuild** is to create models for use with **xwtherm**, some familiarity with that program is useful when working with **genbuild**. References to **xwtherm** will be made in the following discussion. The balance of this document details the use of the program **genbuild**. Its organization mimics the program's user interface with digressions to explain some essential concepts.

## 2. PROGRAM OPERATION

The program runs in an X window environment using OSF Motif, version 1.2 or later, and OpenGL. The program requires a color display that supports the X window pseudo color visual. A pointing device, such as a mouse (preferably 3-button), will be required since some operations cannot be accomplished solely with a keyboard. No unique command line arguments are required. The program supports the common X window command line options. One environmental variable, **XWOTHERM\_BROWSER**, must be set to the name of a program, such as an Internet browser, capable of displaying hypertext markup language (html). This program is used to implement context sensitive help. Use the full path name of the browser. Also copies of

---

<sup>1</sup> Rodriguez, Johnson, La Marre, "Research to Support Scene Simulation and Target Building Capabilities for ACT/EOS", MTU/KRC, PL-TR-96-2177, Phillips Laboratory, January 1996, ADA31812.

<sup>2</sup> Johnson, Curran, Marttila, Yee, Koivunen, Rodriguez, "Phase 2 Development Tasks: Research to Enhance the Phillips Laboratory SIMLAB Capability for Simulating the IR Scene," MTU/KRC, PL-TR-96-2024, Phillips Laboratory, January 1996, ADA307396.

two data files, material.dat and surface.dat, containing surface and material properties should be available in the local working directory.

## 2.1 Example Model and Terminology

For purposes of illustration, a simple generic model is used in the rest of this discussion. This model, shown in Figure 3, represents a cylindrical drum or storage tank that is partially filled with a liquid. The level of the liquid is at the top of bottom row of triangular facets. These triangles will be referred to as elements. While building a generic model, the triangular elements are grouped into Surface Parts. Since surface properties and material properties are assigned to Parts, the user must group together elements that have the same properties and thermal boundary conditions (but not necessarily the same temperature). The drum's elements were grouped into three main parts: top, upper walls, and lower walls. The sides had to be divided into upper and lower walls since they have different interior boundary conditions (i.e., the lower walls are in contact with the liquid and the upper walls are in contact with the air inside the container). For illustrative reasons, the walls are modeled as insulated. A few additional Internal Parts were defined that will be discussed in a later section.

The other major design choice was to select which of the drum's dimensions were to be adjustable. The drum's diameter, height, and liquid level were chosen in this example.

It is important to recognize that the **genbuild** is not limited to dealing with such simple objects and that some of the choices that were made were driven by this model's use as an example.

## 2.2 Main Window

The program is composed of several windows. The main window, shown in Figure 1, is composed of **File**, **Edit**, **Option**, and **Help** buttons; a status line; and a scrollable progress-reporting window. The scrollable progress window should be checked periodically for messages on recently completed operations.

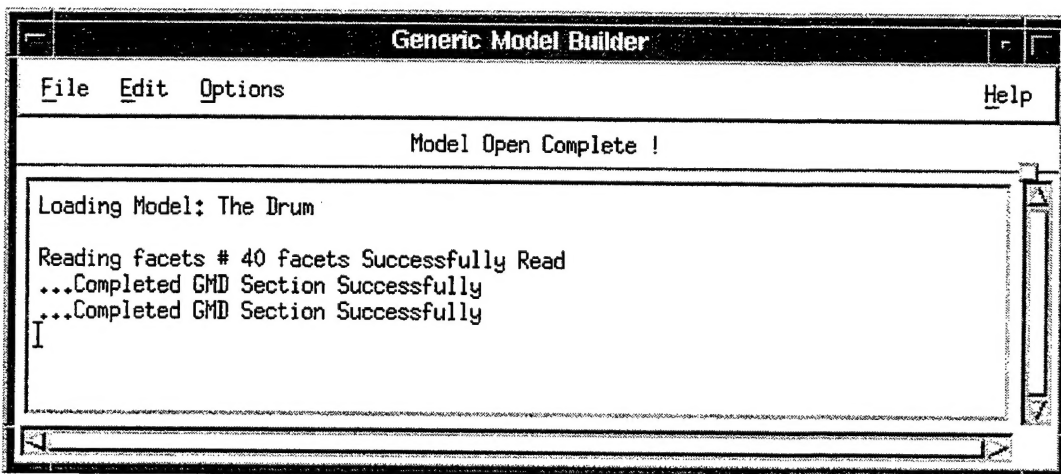


Figure 1. Generic Model Builder Main Window



## 2.3 File Menu

The **File** menu is the normal starting point of **genbuild**. To begin work on a new model, use the left mouse button to select **File** and then **New**. To resume work on a model that was previously edited and saved using **Save** or **Save As**, select **File** and then **Open**.

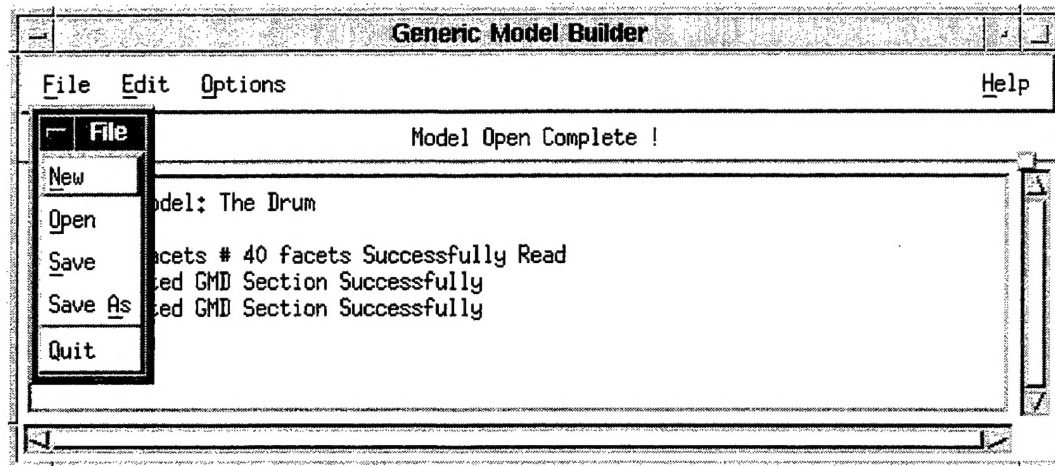


Figure 2. File Menu

### 2.3.1 (File) New

Selecting **File:New** brings up a standard file selection window that initially will show files with a **dxg** file extension. After a file is chosen, the program will attempt to import geometry from the file. The file should be in AutoCAD's text **dxg** format and should contain the surface geometry of a 3-dimensional model expressed in terms of AutoCAD 3DFace primitives. **Genbuild** only imports 3DFaces and the names of AutoCAD levels from the **dxg** file. All other primitives and data in the **dxg** file will be ignored. If a model was constructed using 3-dimensional primitives other than 3DFaces, it may be possible to use operations built into the CAD program to convert some or all of the model's surface representation into 3DFaces. An example of this is the Explode operation available in AutoCAD Version 12 and Corel Cad. Please note that if **dxg** files are imported from another operating systems, such as MS DOS or MS Windows, the **dxg** file may need to be processed to convert from the other system's end-of-line markers to the end-of-line marker appropriate for the current operating system. The program will load the model and display it in the model drawing window shown in Figure 3. The user can select parts and elements (triangular facets), rotate, translate, or zoom the model drawing using mouse buttons and the buttons at the top of this window.

Since the **File:New** operation is limited to importing model geometry, you will **Edit** the model to define adjustable dimensions and the thermal properties necessary for a complete model before saving it in **xwtherm's gmd** file format.

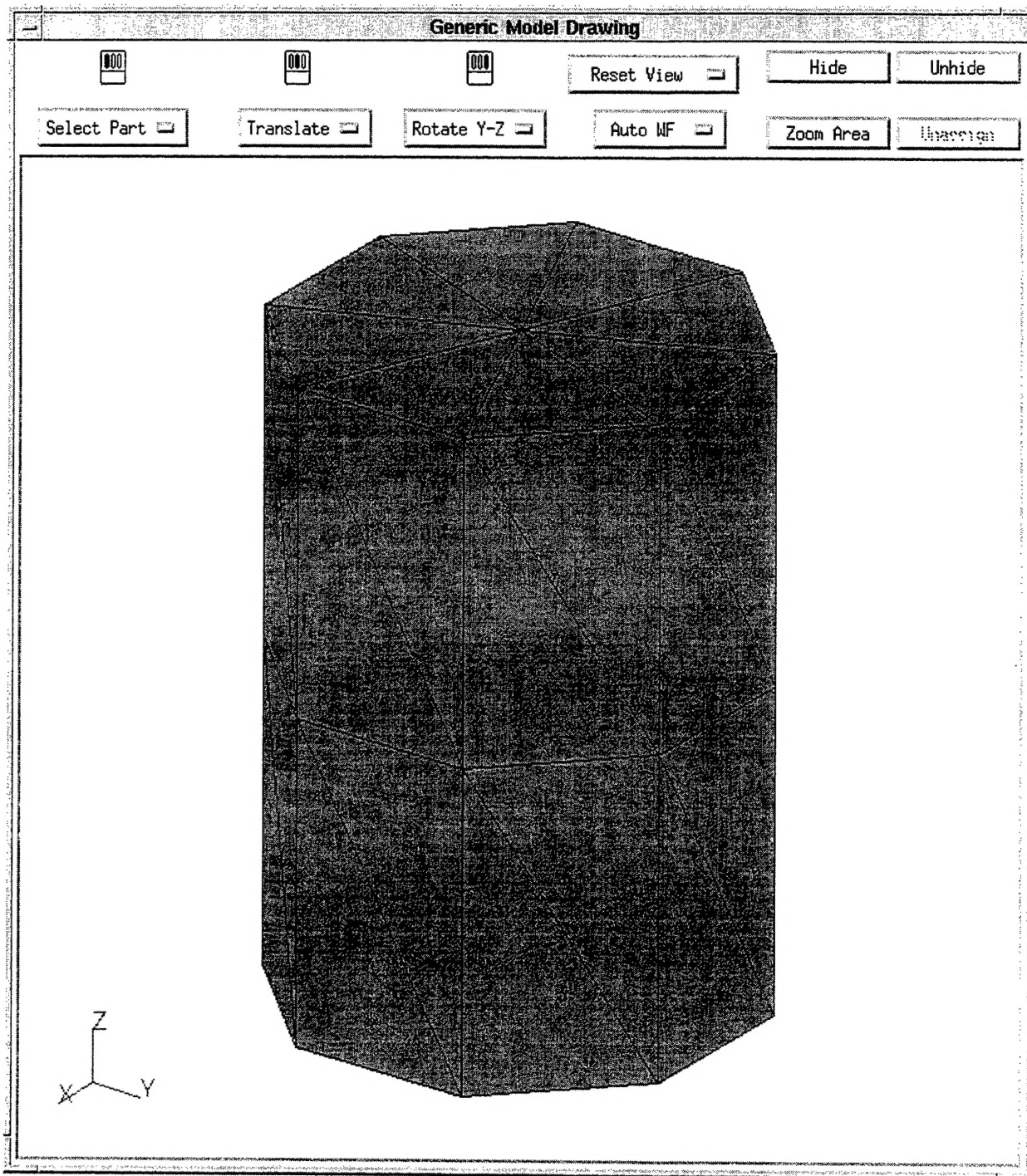


Figure 3. Model Drawing Window

### 2.3.2 (File) Open

Selecting **File:Open** will bring up a standard Motif file selection dialog with file names having a **gmd** file extension. **Gmd** files are generic model definition files. These text files are the native file format of this program and **xwtherm**. Typically, you will open a **gmd** file that was **Saved**

during a previous use of this program. Note that with the advent of this program, some extensions have been made to the format and content of **gmd** files. It is permissible to **Open** an old style **gmd** file in order to use a pre-existing generic model as the starting point of a new model, but some portion of the content will be lost. However, more information will be retained from an old style **gmd** file than can be imported from a **dxg** file using **File:New**.

### **2.3.3 (File) Save**

This selection saves the current state of the model. The default file extension is **gmd**. When the model is complete, the saved file can be moved or copied to **xwtherm**'s model repository. After adding it to the list of generic models in **xwtherm**'s **model.inf** file, the saved model will be available to **xwtherm** to create specific models.

### **2.3.4 (File) Save-As**

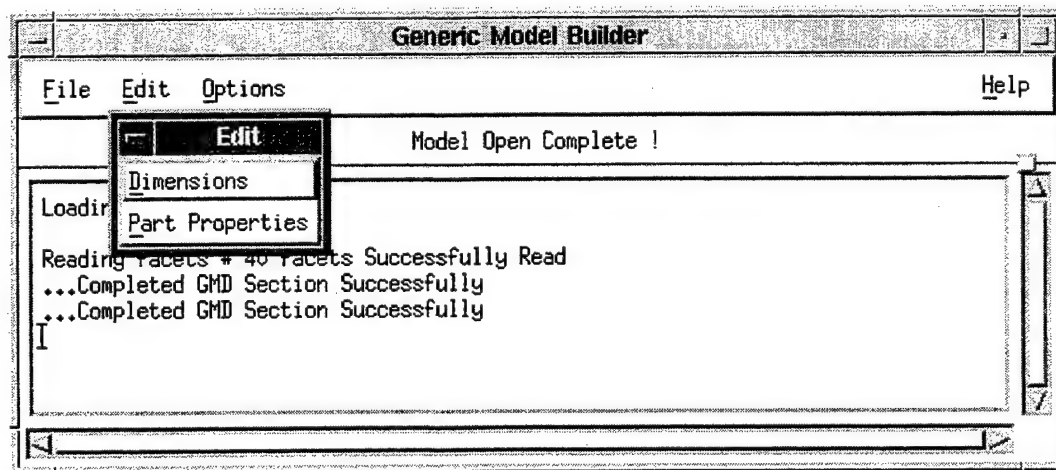
This choice allows you to select a filename for the **gmd** file to which the current state of the model is saved. You will be asked to enter a one-line description or name for the model that will be shown to the **xwtherm** user when your model is selected for use.

### **2.3.5 (File) Quit**

Selecting **Quit** will exit the program. You should save your work prior to exiting the program. Currently, no attempt is made to track if you have made revisions to the model that needs to be saved.

## **2.4 Edit Menu**

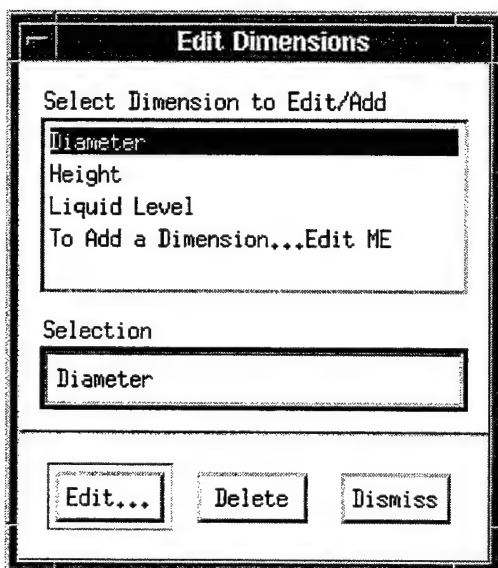
The bulk of the work needed to construct a generic target will be done using the two **Edit** submenus, **Dimensions** and **Properties**. The **Dimensions** submenu is primarily concerned with the definition of adjustable physical dimensions such as length. The **Properties** submenu is used to select lists of material and surface properties *and to detail the construction of the target from a thermal standpoint*. The **Edit** drop down menu is shown below.



**Figure 4. Edit Menu**

### 2.4.1 (Edit) Dimensions

The **genbuild** user will choose zero or more 'dimensions' of the model to make adjustable. Dimensions can be obvious things such as lengths, widths, diameters, and relative locations of some feature of the model with respect to other portions of the model. The diameter, total height, and height of the liquid were chosen to be adjustable dimensions for the drum model. Note that dimensions can be other quantities that aren't even directly realized in the surface geometry of the model, such as the volume of some internal object or the thickness of the drum's lid. One important aspect of a 'dimension' is that, later, the **xwtherm** user will have the opportunity to enter one real value for each dimension that is defined. Since the user-entered value of any dimension can be used in any quantity expressed as an algebraic expression in the generic model, applications for 'dimensions' far removed from the concept as used in engineering drawings can be considered. An example of this would be a flow velocity, although this particular use is not supported by the current version of **genbuild**. Since potential **xwtherm** users will only see the one line description you choose for non-geometric 'dimensions', some restraint has to be exercised to produce an understandable model.



**Figure 5. Edit Dimensions Selection Window**

Upon selection of **Edit:Dimensions**, the edit dimensions selection window will popup with a list of the currently defined dimensions. If the list is longer than the window, a scroll bar will appear on the right of the window. To edit or delete an existing dimension, select it. To add a new dimension, select the last item in the list that is marked with the phrase "To Add a Dimension...Edit ME".

#### 2.4.1.1 (Edit Dimension) Dismiss

Closes the **Edit:Dimensions** selection list.

#### 2.4.1.2 (Edit Dimension) Delete

Deletes the currently selected dimension. In addition to the obvious effects of deleting a dimension, there are some potential indirect effects. As mentioned above, the numeric value of a dimension can be referenced in any algebraic expression used in the model. These

expressions, discussed in the Appendix, are encoded in reverse polish notation, rpn. References to dimensions are by their ordinal number (first, second, ...,  $n^{\text{th}}$  dimension). Therefore, deleting a dimension will not only invalidate any expression that references it, but the deletion also invalidates every expression that references any dimension that followed it in the list. The current software does not attempt to propagate the effects of deleting a dimension on the rpn expressions. Until this feature is added, one strategy to cope with this potential problem is to defer entering complex expressions until the list of dimensions have been largely finalized and to place more 'speculative' dimensions near the end of the list.

### 2.4.1.3 (Edit Dimension) Edit

**Edit Selected Dimension**

Diameter

Range... Minimum 0.010 Nominal 0.625 Maximum 10.000

Expression 0.01 0.625 10

2 Geometric Transform(s) Edit Transform No. 1

Scale Direction Line Visible Length 0.625

Select Direction FROM Point ( 0.120, -0.289, 0.864)

Select Direction TO Point ( -0.120, 0.289, 0.864)

Select CENTER Point ( 0.000, 0.000, 0.000)

Xform Magnitude-rpn xal 0.625 / Default

Select Objects to be Transformed

Select Elements

Dismiss

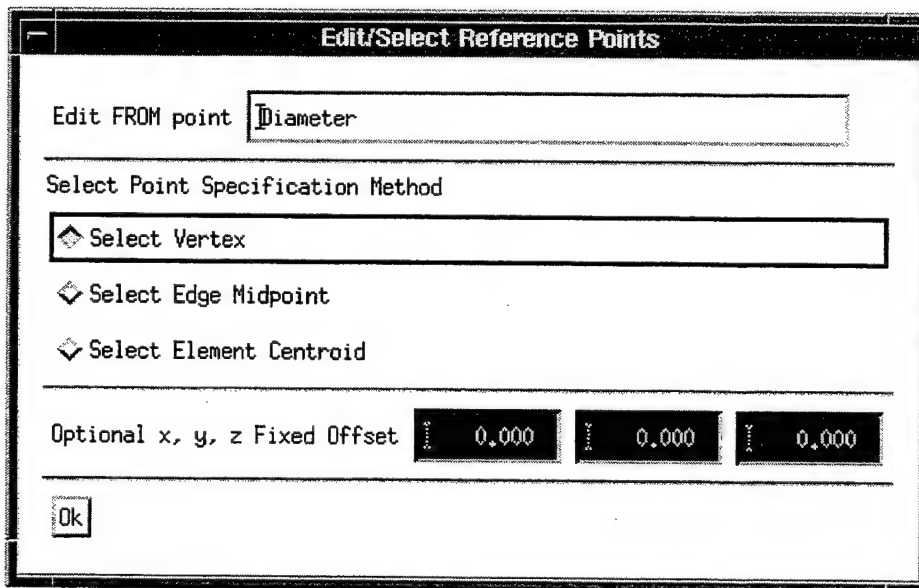
After a dimension is selected and the **Edit** button is depressed, the Selected Dimension window appears to define or edit the dimension. The window is divided into 5 sections, corresponding to the 5 items that may be required to completely define an adjustable dimension, such as the diameter of the example drum shown in Figure 6.

**Figure 6. Edit Selected Dimension**

- 1) The first item is a one-line text box used to describe the dimension to a subsequent **xwtherm** user of your model. If the dimension does not have a visually obvious expression on the model that can be illustrated with a "dimensioning symbol" (see below), more care will need to be taken with this description.
- 2) Enter minimum, nominal, and maximum values for the dimension as algebraic expressions in reverse polish notation. As in Figure 6 above, they can be simple constant numeric values or they can be nontrivial expressions involving any combination of the dimensional values that a current **xwtherm** user has entered. Nonsensical values can make the model unusable, since **xwtherm** will not accept a value less than the current minimum nor greater than the current value of the maximum. Carefully chosen minimum and maximum expressions can prevent a subsequent **xwtherm** user of the model from entering unrealistic values and producing erroneous results.

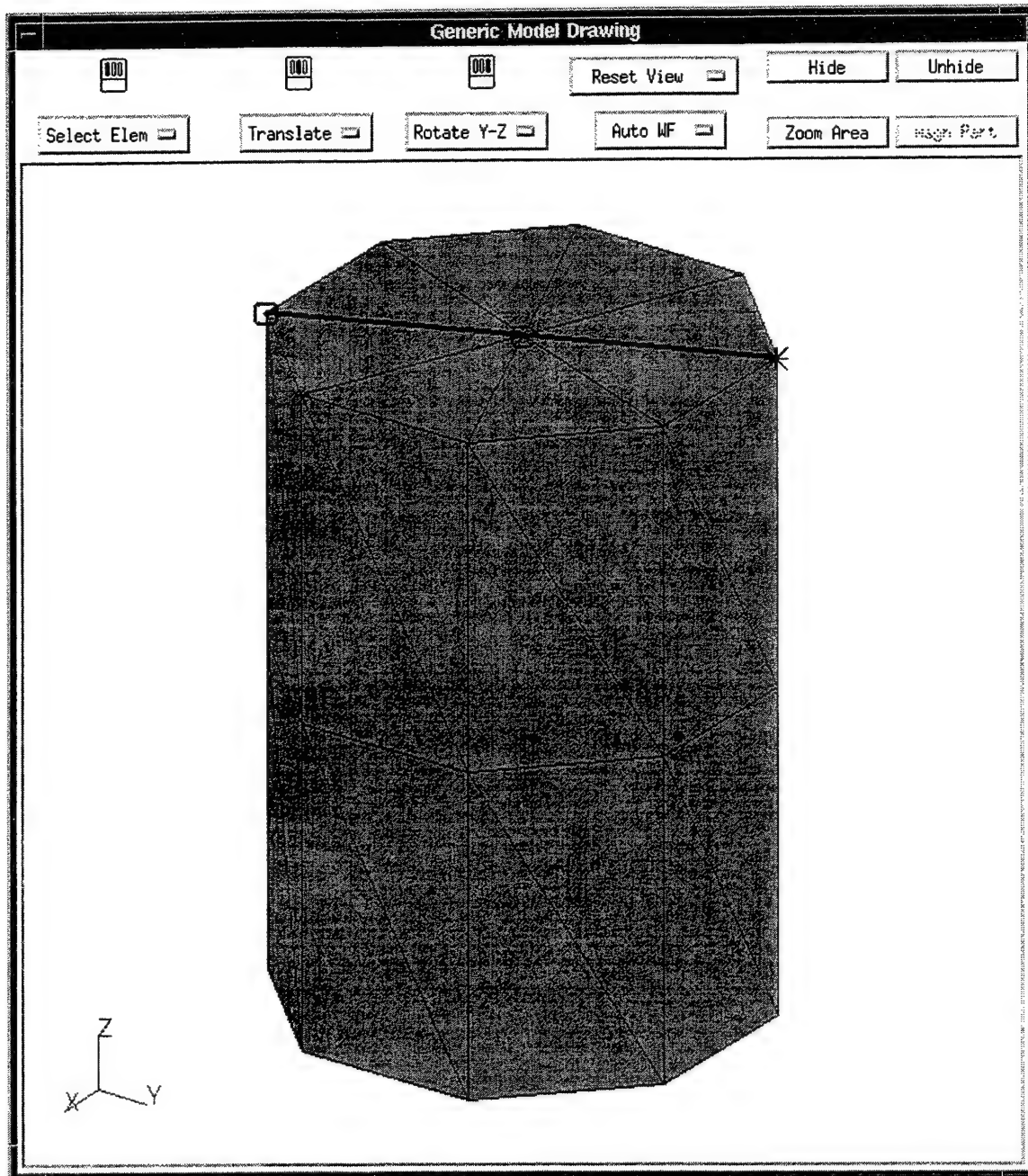
- 3) For dimensions that do affect the surface geometry of the model, determine one or more geometric transformations that when applied will actually re-dimension the model. Currently, the available transformations are linear translation and scaling along a single direction. We plan to add a rotational transformation, already supported by **xwtherm**, in the near future.

First, enter the number of transformations needed to produce the re-dimensioning. If a dimension does not change the surface geometry, keep the number of transforms set to zero and skip the rest of this window. Using the drum diameter as an example of a normal adjustable dimension, note that it requires two linear scale transformations to adjust the diameter of the drum shown in Figure 6. Equal scale factors are applied along two perpendicular diameters. Next, enter the index of the transformation you wish to define or edit, 1 or 2 in the example above. The balance of this section, formerly "grayed out" will become active. To define the direction for a translation, you must pick 2 points on the model, a "From" point and a "To" point. To define the direction of a scaling, you choose three points, "From", "To", and "Center". The "Center" point actually defines a plane perpendicular to the "From-To" line about which the scaling will be performed. The "Center" point need not lie along the "From-To" line. The window that pops up during the selection of this transform direction line selection is shown below in Figure 7. Figure 8 shows the model after all three points have been selected for one of the two scale transformations that will be used to adjust the drum's diameter.



**Figure 7. Transformation Direction Reference Points Selection**





**Figure 8. Scale Direction Line with “From”, “To”, and “Center” Points**

The actual transformation direction reference points are picked directly on the model drawing. If the button on the extreme left of the model drawing indicates “Select Part” selection, as it does in Figure 3, use the left mouse button to change it to “Select Element”. You then pick a reference point of “From”, “To”, or “Center” using the left mouse button. You may pick a single vertex, the midpoint of the triangle edge connecting two adjacent vertices, or the centroid of a triangle in the Reference Point window. If you wish, you may enter a fixed x, y, z offset (in meters) of the reference point with respect to the selected point. After you Ok the selection of both a “From” and “To” point and returned to the Edit Selected

Dimension Window (Figure 6), the coordinates of the reference points and the length of the direction vector are shown. In the above example, the length of the direction vector is 0.625 meters. This also happens to be the default diameter of the drum that is being used as an example. This information will be used in the next section. The final item in this section is the button labeled as "Visible" in Figure 6. This button toggles between "Visible" and "Not Visible". When this button is toggled to the "Visible" state, the model viewing direction, magnification factor, and this transformation vector will be recorded as a "dimensioning symbol" for use by **xwtherm** in the **gmd** file. Chosen judiciously, this can be a valuable visual clue to a future user of your model. Chosen poorly it can be misleading or confusing to the final user. Note that though **xwtherm** uses the viewing direction and magnification passed to it through the **gmd** file, it will reposition the image so that the "dimensioning symbol" is centered in the viewport. Finally, **xwtherm** will accept at most one "dimensioning symbol" per dimension.

- 4) For each transformation defined, enter an algebraic expression, in **rpn**, that will evaluate to the correct "magnitude" for the transformation. For translation, this will be a signed displacement in meters along the transform direct (positive, negative, or 0.0). For scaling, this expression should be evaluated to a dimensionless scale factor, strictly greater than 0.0, to be applied along the scaling direction. The value 0.0 should be avoided for a scale factor since using 0.0 will project the entire model into the "Center" plane. Negative scale factors will turn all or part of the model "inside-out". Avoiding such unacceptable values is accomplished by setting appropriate minimum and maximum range values as described in 2) above. For rotation (future feature), it is anticipated that this expression should evaluate to an angle in degrees for a rotation about a rotation axis using the right-hand rule convention.

Clicking the default button will generate an **rpn** "magnitude" expression that may be appropriate for the transformation, based on some assumptions about how direction vectors will be chosen. For the example used here, the default **rpn** expression is "**&a1 0.625 /**", where "**&a1**" stands for the value that the **xwtherm** user will enter for the drum's diameter, since it was chosen to be the first adjustable dimension, and 0.625 is the nominal drum diameter. In this case, the default expression does evaluate to the correct scaling factor, the ratio of the desired diameter to the current diameter. If the default expression is not correct, enter the correct expression.

- 5) The final item is to select the elements (triangles) to which the transformation will be applied. Again the selection of which elements to apply the transformation to is made by using the left mouse button on the model drawing after clicking the "Select Elements" button in the fifth panel of the "Edit Selected Dimension" window shown in Figure 6. Elements selected on the drawing with the left mouse button will be redrawn in magenta. Note that holding down the control key and "dragging" a rubber-band box will select all the elements within the dragged box. Clicking on a previously selected element will deselect it, returning the element to its original color. No further action is required to designate the elements that will be transformed. Future versions of this program may support the selection of other geometric entities such as individual vertices or collections of elements such as "parts".



### 2.4.2 (Edit) Properties

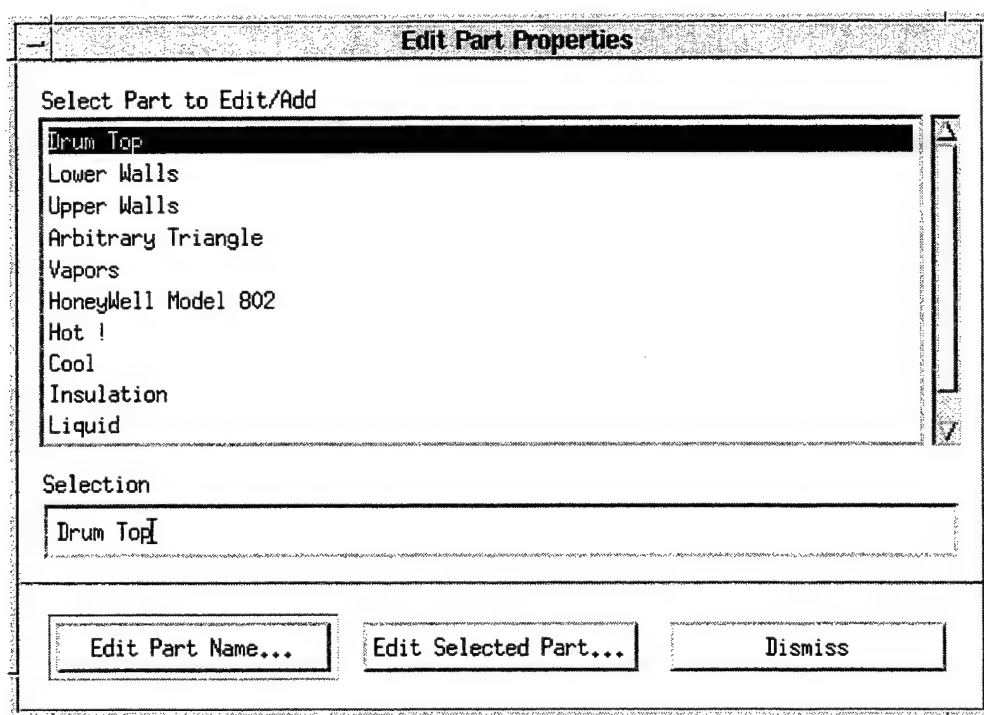
Each generic model is composed of one or more named "parts". Each part is assigned properties and the interconnection of these "parts" produces a thermal network model whose solution under the specified environmental and operating conditions produces the thermal and infrared signature predictions. A part can be one of four types; a Surface Part, a (passive) Internal Part, a Controlled Temperature Part, or a Heat Source Part. Note that the four types are not perfectly distinct. For example, a controlled temperature part can be part of the model's surface or an internal (though non-passive) part. Parts and their properties are discussed in detail below.

- 1) A surface part must have one or more of the triangular elements that make up the model's surface geometry uniquely assigned to it. A surface part with no surface elements will be *deleted* when the **Properties** submenu is exited. A surface part should have a list of one or more 'preferred' surface properties assigned to it. A future **xwtherm** user will see the "preferred" list of materials and intuitively take it as a list of surfaces recommended for that part and only resort to the global list when needed. Unless the surface part is also a controlled temperature part, a surface part should have one or more layers of defined thickness assigned to it. A surface part will usually have a list of one or more 'preferred' materials assigned to it. The first preferred list entry is needed to produce a well-defined default model, and so the generic model will not be complete until there is at least one "preferred" surface property and material property for each part that requires them.
- 2) A passive internal part can be used for one of two purposes. It can be used to represent some passive internal thermal mass, such as the liquid or the vapor above the liquid in the example drum. In this case, the part should have exactly one 'layer' of a specified thickness and specified area assigned to it. It should also have a preferred material list with at least one entry associated with it. Internal parts will not require surface properties. The other use for an internal part is to allow some of the layers of a surface part to be composed of a material different from the rest of the layers. To stretch the current illustration, suppose the drum being modeled was not a common container, but had insulated walls with an outer metal sheath, a layer of insulation, and an inner metal liner. The drums walls could be modeled as a surface part with three or more layers and a list of metals that are "commonly" used to construct the outer sheath and inner liner of such drums. You could then define a "Drum Wall Insulation" internal part and give it a preferred list of insulating materials and associate it with the middle wall layer(s). The first and third layers would assume whatever material properties a future **xwtherm** user assigns to the drum (surface) part and the middle layer will assume whatever material is assigned to the "Drum Wall Insulation" part by the **xwtherm** user.
- 3) A controlled temperature part would represent a portion of the model that operates at a constant temperature or has a known time versus temperature characteristic. Currently, neither **genbuild** nor **xwtherm** incorporates a "curve editor". A user can use a text editor or similar means to enter time-temperature curve data. Constant temperature sources (that are not time dependent) are currently supported since the user enters a single value in the Controlled Temperature input field (see Figure 11). Assigning preferred surface properties, preferred material, or layers to an internal controlled temperature part is not necessary and

will not have any effect on the final results. A preferred surface properties list with at least one entry should be assigned to a controlled temperature part that is assigned some of the model's surface elements.

- 4) A heat source part should have a heat rate, in watts, assigned to it. The heat rate can be positive or negative. This data is written as a power-time curve with one time point, effectively making it a constant power source. Currently, one must use means outside of **genbuild** and **xwtherm**, to utilize a time verses power profile (i.e., simple text editing in the **par** section of the **gmd** file). All other characteristics that you may assign to this type of part are ignored since this is treated as a heat source/sink that the user will connect to appropriate other parts.

Upon selecting **Edit:Properties** the Select Part dialogue, shown in Figure 9, appears.



**Figure 9. (Edit Properties) Part Selection Dialog**

The Edit Properties window is a slightly modified Motif selection widget. You should first select a part to edit or add.

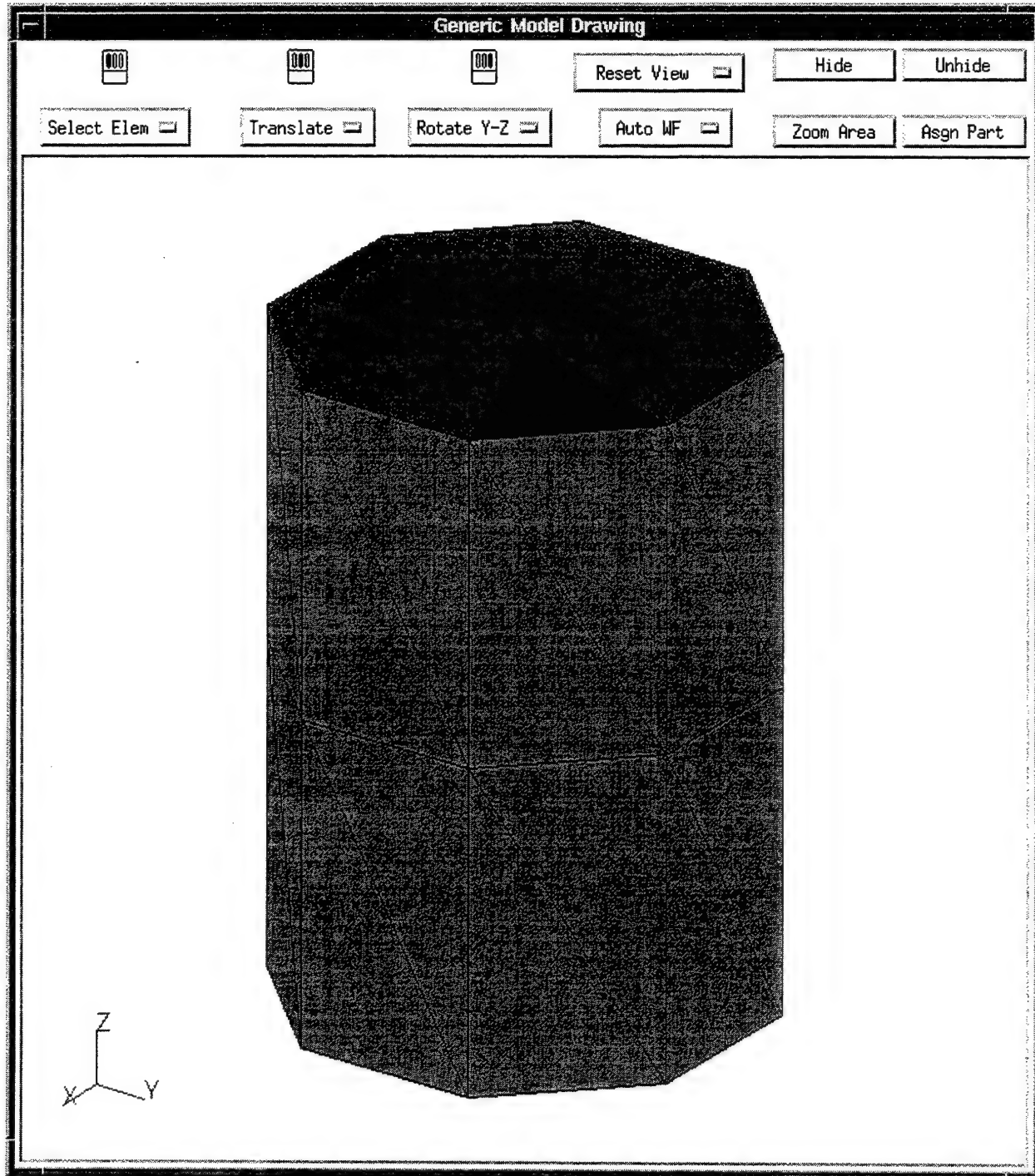
#### **2.4.2.1 To Add a Part**

To add new part selections, the last item in the list, labeled "To ADD a Part...Edit My Part Name" and then depress the Edit Part Name... button, enter a name for the part and click Ok. Since the phrase you choose may be the only representation of the part to the eventual **xwtherm** user, the descriptive phrase should be expressed more meaningfully than the example above. Note that new parts are designated as Surface Parts with no surface elements assigned to the new part. As such, the new part will be deleted if you dismiss the parts selection dialog. If the new

part is a Surface part, assign surface elements to it before exiting this dialog. If the new part is not a Surface part, activate the Define Properties... menu and change the part type. Both of these operations are described below.

#### **2.4.2.2      Assigning Surface Elements to Surface Parts**

Assigning surface elements (triangles) to surface parts, employs two windows, the Part Selection Dialog shown in Figure 9 and the Model Drawing, shown in Figures 3 and 10. The most efficient approach is to set the Model Drawing to Select Elem mode with the button in the upper left of the Model Window (the button is marked Select Part in Figure 3; Select Elem in Figure 10). Next, in the part Selection Dialog, highlight the part that is to get new surface elements. The part that is to be assigned additional elements will be redrawn in green. Use the left mouse button to pick elements, visible in the Model Drawing Window, that are to be added to the selected part. Picked elements will be redrawn in magenta. After you have selected one or more elements to add, the Asgn Part button in the right, upper part of the Model Drawing will become active and should be depressed to complete the assignment. As the elements are assigned, they will be redrawn in green. As before, you can pick multiple elements for assignment by holding down the control key and dragging a window that contains elements. Picking a selected element deselects it. Additionally, the Hide and Unhide buttons can be employed to aid in the process.



**Figure 10. Assigning an Element to a Surface Part, the Drum's Top**

#### **2.4.2.3 (Edit Properties) Define Properties**

Every part will require some additional definition of its properties. Click the Define Properties button to bring up the window shown in Figure 11.

Edit Selected Part Properties

Part: Lower Walls

SURFACE Part

Preferred Surface List...

C\_STEEL,BLACK

Preferred Material List...

CARBON STEEL

Edit Part Layers...

4 Layer(s)

Interior Boundary Connected to Part

10

Interior Boundary Heat Xfer Coef (W/(C\*m^2))

8.000

Controlled Temperature(C)

0.000

Heat Source/Sink (Watts)

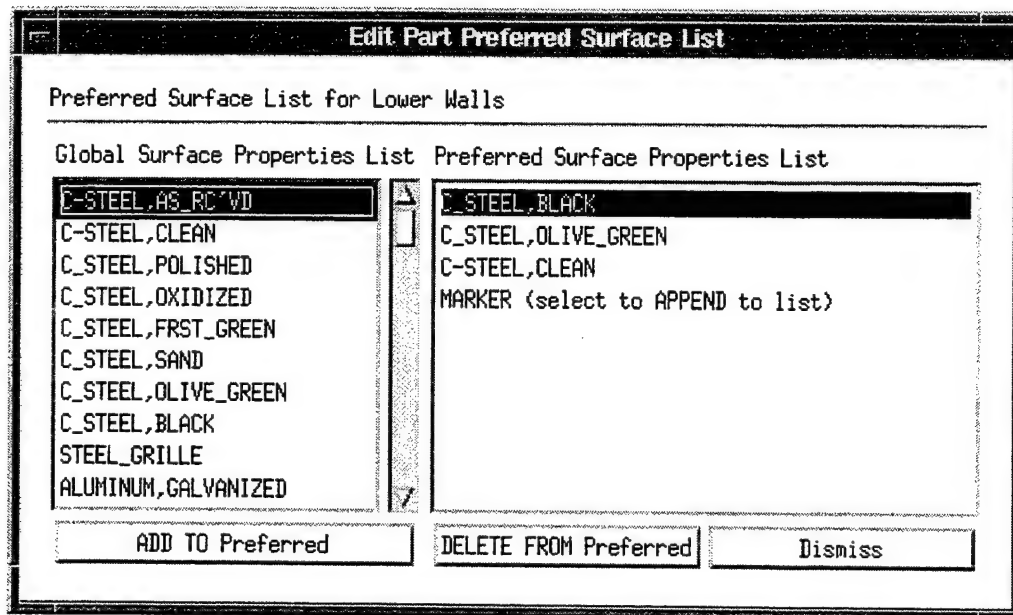
0.000

Dismiss

**Figure 11. Define Properties Window**

The Window is divided into 8 sections. The button in the first section cycles through the 4 part types: Surface, Internal, Controlled Temperature, and Heat Source/Sink. Since the way in which a part is incorporated into the thermal model is partially determined by its type, the appropriate type should be selected.

The next section is the Preferred Surface List... buttons. Activating this button brings up the dual selection list shown in Figure 12.



**Figure 12. Surface Selection List**

The “global” list on the left is composed of all the names of all the surface properties that were read in from the local copy of surface.dat. Surface.dat is a simple text file that you can edit to incorporate surface property data for use in these models. The “preferred” list will start with only the “Marker (select to Append to list)” item. For every Surface Part in the model, a preferred list of one or more surface “finishes” should be constructed. Build up this “preferred” list by selecting an item from the global list and copying it to the list at the selected position using the Add TO Preferred button at the lower left of the window. Items can be deleted from the preferred list by selecting them and activating the Delete FROM Preferred. The first position in the list is special in that it is taken to be the default surface finish for the part.

The third section of the property definition pane contains the Preferred Material List..., the operation of this list selection is similar to the surface selection described above and will not be repeated. The data for the “global” material list comes from the local text file material.dat, which may also be edited to include specialized or updated material property data. For the preferred material list, again the first item is taken to be the default material. Surface parts (that are NOT temperature controlled) and internal parts should have non-empty preferred material lists.

The Edit Part Layers... in the fourth section activates the window shown in Figure 13. This window is used to define one or more ‘layers’ of material for those parts that require layers. Surface parts (again excluding any that are designated as controlled temperature) should be assigned at least one layer. Internal parts that represent isothermal, passive thermal masses should be assigned exactly one layer. Other part types cannot use layers.

**Edit Part Layers**

Lower Walls  

4

Layer Count

Copy Changes Down

Thickness(m)	Area(m^2)	Ref-Part#	Part-Name	Default Material
0.002	0.000	2		
0.002	0.000	2	Lower Walls	(CARBON STEEL)
0.005	0.000	9	Insulation	(GLASS_WOOL)
0.005	0.000	9	Insulation	(GLASS_WOOL)
0.002	0.000	2	Lower Walls	(CARBON STEEL)

Dismiss

**Figure 13. Editing Part Layers**

An item requiring further explanation is the Copy Changes Down button. When this button is in the copy down state, changes made to the thickness, area, or reference part of the selected layer will be copied to all layers that follow the selected layer. This is very convenient if a large number of layers are defined that have similar properties. Pressing this button toggles the button to "Change Selected Only".

- 1) Surface parts should generally be assigned one or more layers. There are two potential reasons to assign 2 or more layers. Both reasons are illustrated by the example shown in Figure 13. Recall that our example drum has walls made of an inner and outer sheath with a middle insulating layer and thus has layers of different materials. The other potential reason is to subdivide a layer that may have a large temperature gradient across it under some expected conditions to maintain the accuracy of the thermal solver. In the current example, if the insulated drum contained extremely hot or cold liquid, then there would be a large temperature gradient across the insulating layer and subdividing the insulation into two more layers would improve the accuracy of the solution. Subdividing layers can be taken to an extreme that can degrade the accuracy of the thermal solution particularly if they are thin and have high conductance material. Surface parts should have the correct thickness assigned to each layer. ***It is acceptable and generally preferable to leave the Area set at 0.0 for Surface Parts.*** The reason is that the program will substitute the actual area of the surface elements assigned to a surface part for a zero surface area. If the area is entered as non-zero, the entered value will be used and the true surface area ignored. The reference part number designates the part whose current surface and bulk property selection is used to compute the thermal properties of each layer. The default reference part is the part to which the layers belong (i.e., part 2 for sample shown in Figure 13). Note that the reference part has been changed to part 9 for the middle 2 layers. Apparently part 9 represents the insulation used in our insulated drum.



- 2) Passive internal parts should be assigned one layer. Correct values should be entered for the thickness and area of these parts, since there is no associated geometry from which to obtain any dimensions.

The fifth section of the property definition window allows parts to be connected to other parts. There are several stringent restrictions. The first restriction is that the originating part must have a well-defined cross-sectional area(s). The second is that a single temperature must describe the part being connected. One kind of connection would be from surface parts to other parts including internal parts, controlled temperature parts, or heat source parts (i.e., connections to other surface parts are NOT currently allowed). A second possibility would be to connect internal parts that have a specified area to other internal parts, controlled temperature parts, or heat source parts.

The sixth section should only be filled in for controlled temperature parts.

The seventh section should only be filled in for heat source/sink parts.

## 2.5 Options Menu

The **Options** menu supports 2 options as shown in the Figure below.

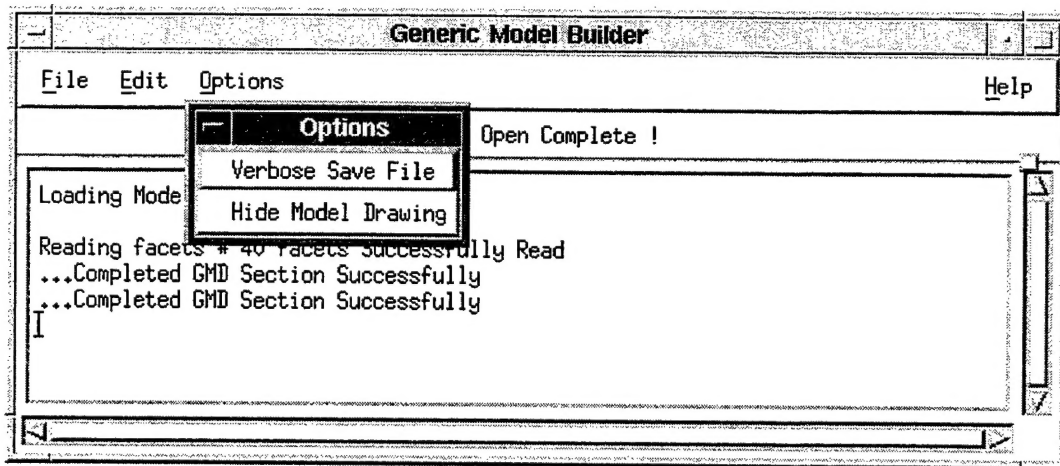


Figure 14. Options Menu

The first option toggles between terse and verbose format for the **gmd** file, the native save file format for this program. The verbose format imbeds additional comments in the **gmd** that will make the file format more understandable to anyone requiring details about its contents. The second option pops the Model Drawing window up and down. As an alternative, pressing the Escape key can hide the model window, when the Drawing window has focus.

## 3. DISCUSSION

This program provides the capabilities to create new generic target models easily through the use of graphical components built into the user interface. This opens up the prospect of developing a larger inventory of generic targets and the ability to develop generic targets more rapidly when special needs arise. Through the use of the generic target builder's companion program,



**xwtherm**, and a larger inventory of generic targets, specific models tailored to match the actual targets that of are interest can be rapidly produced. The alternative is to pick some target model from a very limited collection of non-generic models, none of which may have the correct dimensions, surface properties, or materials.

Once the user has selected the menu inputs in **xwtherm** for model modifications, an infrared prediction can be made with the signature code **TCM2**. The output products of **TCM2** are then used in the Phillips Lab **Scene Builder**.

Limitations and planned new features have been described throughout the Program Operations sections where applicable. Other enhancements are also planned in the future and are documented outside of this report. As user feedback is obtained through exercising this new tool, additional modifications can be expected in the future.

## APPENDIX

### A.1 RPN Expressions

With generic models there are numerous instances where an expression must be evaluated to determine some physical quantity, for example there may be a need to encode a formula to compute the volume of a cylindrical region from its diameter and height. To handle such problems, formulas and similar expressions are encoded in generic models in a specialized form of reverse polish notation, hereafter referred to as rpn expressions. Although rpn expressions are not uncommon, the precise format of these expressions as used in generic target models is unique, and so is described below.

A valid generic model rpn expression is composed of one or more operands followed by zero or more operators. The operators and operands are separated from each other by one or more spaces and/or tab characters. As is characteristic of rpn expressions, the operands must precede the operators that operate on them and the expression is evaluated in strict left to right order.

Only two types of operands are supported. An operand can be a signed numeric constant in base 10 integer (for example 923), floating point (for example -273.15) , or scientific notation (for example +9.1e-31). Numeric operands are read and processed as single-precision floats using the standard C library functions. The other type of operand is represented as the string "&aN", where N is a number between 1 and the number of "dimensions" defined for the generic model in which the expression is used. &aN stands for the current value of the N<sup>th</sup> dimension. Referring back to the example shown in Figure 5, &a1 would be the current drum diameter, &a2 would be the current drum height, and &a3 would be the current depth of the liquid in the drum. An example of a complete generic model rpn expression would be

3.14159 &a1 &a1 \* \* 4 / &a3 \*

which is equivalent to (pi times the diameter squared divided by four) times the depth of the liquid and evaluates to the volume of the liquid in the drum.

Two types of operators can be used: unary and binary. In a valid expression, a unary operator must be preceded by at least one operand when it becomes a candidate for evaluation. When evaluated, a unary operator will consume the operand to its immediate left and the result of the evaluation will replace the operand and operator. Binary operators must be preceded by at least two operands when it becomes a candidate for evaluation. When evaluated, a binary operator consumes the two operands that immediately precede it to the left and the result replaces the 2 operands and the binary operator. All operators are encoded as a single character

The unary operators currently supported by generic models are

a	arctangent(operand)	" 1 a" evaluates to 45.0
s	sine(operand in degrees)	"30 s" evaluates to 0.5
c	cosine(operand in degrees)	"30 c" evaluates to 0.866..

The binary operators are

+	addition	"1 2 +" evaluates to 3.0
-	subtraction	"7 5 -" evaluates to 2.0
*	multiplication	"-1.3 3 *" evaluates to -3.9
/	division	"7.0 2.0 /" evaluates to 3.5
<	retain lesser of operands	"1.3 -3 <" evaluates to -3.0
>	retain greater of operands	"2.5 2 >" evaluates to 2.5
^	operand1 ^ operand2 (power)	"3 4 ^" evaluates to 81.0

Since these operations are performed using the standard operators and math libraries supplied with C compiler implementations, the usual restrictions apply to the permissible domains of these operators.

The final requirement is that after operators have been evaluated, exactly one numeric value be left. This last number is the value of the expression.